REMARKS

In the Office Action of February 19, 2002, Claims 1, 2, 4 - 7, 9 and 10 were rejected. No claim was allowed. In response, Claims 1 and 6 are amended. A marked-up copy of the changes made is attached hereto. Reconsideration and reexamination are respectfully requested in view of the following remarks.

Rejection of Claims 1 - 10 under 35 U.S.C. §112, second paragraph

Claims 1 and 6 were rejected under 35 U.S.C. §112, second paragraph, as being indefinite. The Examiner alleges that it is uncertain whether the insulating film of Claims 1 and 6 insulates electrically or thermally. In response, Claims 1 and 6 are amended to specify that the film insulates electrically. It is respectfully submitted that this meaning is clear from the specification in the first paragraph, which established the context and background of the invention as relating to etching of an insulating film such as silicon oxide of a wafer. In this context, it would be clear to persons skilled in the art that the insulating film would be an electrically insulating film. Accordingly, it is respectfully submitted that no new matter is added by this amendment.

It is therefore respectfully submitted that the

rejection of Claims 1 and 6 is thereby overcome.

Rejection of Claims 1, 2, 4, 5, 6, 7, 9 and 10 under 35 U.S.C. §103 over Satou et al in view of H. Nishino et al

Claims 1, 2, 4, 5, 6, 7, 9 and 10 were rejected under 35 U.S.C. §103 as obvious over Satou et al (U.S. Patent No. 5,961,850) in view of H. Nishino et al. The Examiner takes the position that Satou et al teaches various limitations of the claimed invention, as listed in items i. through viii. on pages 4 - 5 of the Office Action. The Examiner acknowledges that Satou et al does not teach (ix.) a gas that contains at least carbon and fluorine wherein a gas species is generated which contains carbon and fluorine according to a plasma dissociation, and (x.) plasma generation means which generates a plasma in which the degree of plasma dissociation is a "middle" degree and the gas species containing carbon and fluorine is generated fully in the plasma. The Examiner alleges that Nishino shows (xi.) a gas that contains at least carbon and fluorine wherein a gas species is generated which contains carbon and fluorine according to a plasma dissociation, and (xii.) a plasma processing apparatus comprising plasma generation means in which the degree of plasma dissociation is a "middle" degree and the gas species containing carbon and fluorine is generated fully in the plasma. The Examiner takes the position that it

would be obvious to implement H. Nishino et al's fluoromethane as Satou et al's etchant gas. The Examiner alleges that motivation for implementing Nishino's flurormethane is drawn from "common industrial practices" and as discussed by Nishino that the gas can be used when rough Si surfaces can be smoothed and Si trench corners can be rounded off." With respect to limitation that the claimed frequency be between 300 MHz and 1GHz, the Examiner takes the position that it would have been obvious to reduce the microwave frequency power application as allegedly taught by H. Nishino et al in order to impart the desired extent of dissociation. The Examiner alleges that motivation for reducing the microwave frequency power application as allegedly taught by Nishino is to impart the desired extent of dissociation is "well known in the art." Further, the Examiner alleges tha Satou provides specific motivation for selecting alternative etching gases as influencing "wafer yield stability and reliability."

This rejection is respectfully traversed as it may apply to the claims as amended herein. The present invention is directed to a plasma processing apparatus and method using a gas containing gas species that contain fluorine and carbon. Features that distinguish the present invention from the methods described in the cited references include that the degree of plasma dissociation

is a middle or intermediate degree (that is, a relatively high level of CF_2, and CF compared to the amount of F) and that a side wall of the vacuum processing chamber is controlled to have a range of 10 °C to 120 °C. As explained more fully in the specification, for example, on pages 2 - 3, a middle or intermediate degree of dissociation is desirable for etching silicon oxide. As explained more fully in the specification, for example on pages 9 - 11, the low temperature of 10 °C to 120 °C for a side wall of the vacuum processing chamber serves to limit the amount of gas discharge from reaction products that become deposited on the side wall. The range of 10 °C to 120 °C is selected as being significantly lower that the desorption temperature of the reaction products. The amount of gas discharge from the surface of the side wall remains limited and stable even when there are temperature fluctuations of ± 10 °C, thereby providing more stable deposition conditions. Thus, the combination of both having a plasma degree of association that is in the intermediate range and having side walls maintained at a low temperature of 10 to 120 °C provides advantageous effects of enabling etching at high selectivity without the requirement, for example, of CH_2 from the wall surface.

As stated previously, these features are neither disclosed nor suggested by the cited references. In particular, Satou et al does not disclose processing with

gas species containing carbon and fluorine. There is no teaching or suggestion in Satou et al of controlling the extent of dissociation of a processing gas or of using a plasma excitation frequency of 300 MHz to 1 GHz. With respect to the temperature of the side wall, the reference teaches that the temperature of the side wall of the processing chamber should kept at a high temperature to prevent the deposition of reaction products on the side wall of the processing chamber. On the other hand, in the apparatus and process of the present invention, the temperature range of the side wall of the present invention is maintained to be much lower than the desorption temperature of the reaction products of the particular process of the present invention.

Moreover, H. Nishino et al does not supply the elements missing from Satou et al. H. Nishino et al describes a etching treatment of silicon wherein a mixture of CF_4 and O_2 are discharged within a quartz tube by applying a 2.45 GHz microwave to generate "fluorine and oxygen atoms". There is nothing in H. Nishino et al to suggest a generation of "gas species containing carbon and fluorine" (that is, gas molecules containing both carbon and fluorine, such as CF, CF_2, etc.) with a middle degree of dissociation of the gas by providing a plasma excitation frequency of 300 MHz to 1 GHz. Therefore, the Examiner's statements in xi. and xii. regarding what is

disclosed in H. Nishino et al are in error.

The Examiner takes the position that it would be obvious, as a matter of optimization, to reduce the microwave frequency power application from 2.45 GHz to the range of 300 MHz to 1 GHz to impart the desired extent of dissociation. It is respectfully submitted that there is nothing in H. Nishino et al to suggest any desirability of achieving lesser degree of dissociation than the generation of "fluorine and oxygen atoms", particularly since H. Nishino et al does not relate to the etching of an electrically insulating film wherein gas species such as CF and CF_2 are desirable. Therefore, there is no motivation in H. Nishino et al to reduce the microwave frequency power that is applied to the CF_4 and O_2 to achieve a reduced dissociation of CF_4.

The following is a more detailed comparison of Satou et al and H. Nishino et al with the present invention:

According to the Examiner, Nishino's article describes in section IIIA that "frequency of the plasma source is 2.45 GHz (Fig. 1), and the degree of dissociation of the plasma containing fluorine (F) and carbon (C) is middle".

However, Nishino's article contains no descriptions regarding the plasma dissociation and no descriptions stating that the degree of the plasma is middle at all.

Further, according to the Examiner,

"lowering of the frequency of the plasma source to 2.45 GHz or lower to condition the degree of dissociation to a desired level is an ordinary technique, which is described in Nishino".

However, Nishino's article has no such descriptions at all.

Further, the Examiner also comments that

"Nishino describes that CF or CF2 is desirable as the gas species".

However, Nishino's article does not contain such descriptions at all.

Nishino uses CF_4/O_2 plasma for smooth etching of side wall in polysilicon etching. Accordingly, since the silicon surface is oxidized with oxygen to form thin oxide films (SiO_2), oxide film etching may occur in that F etches the oxide film. However, there exists a distinct difference between a case where the film itself is an insulating film such as an oxide film and a case of etching for silicon in view of the etching mechanism as will be described below.

Generally, silicon is reacted with F to form a volatile gas such as SiF4 and applied with etching. When silicon is etched by the F and C—containing plasma in an etching atmosphere for insulation films, CF type deposition films are formed on the silicon surface. Then, when ions are irradiated thereon, F and Si are reacted

into SiF_4 or the like and detached. However, C increases gradually on the silicon surface and, finally, silicon etching is stopped. On the other hand, on the surface of the silicon oxide film (SiO_2), CF_3 deposition films are also formed and reaction products such as SiF_4 are formed by ion bombardment to allow etching to proceed. In the case of the SiO_2 film, oxygen O after etching of Si is reacted with C in the deposition films and detaches as volatile gases such as CO or CO_2. Accordingly, in contrast to what happens with a silicon surface, the deposition films on an insulating film such as silicon oxide are thin and etching proceeds continuously.

In Nishino's article, since oxygen O_2 is added to CF_4, it has an effect of removing the silicon deposition films and etching is continued. F reacts with any one of Si and SiO_2 to allow etching to proceed. Accordingly, selectivity cannot be obtained, for example, in a case where the underlying substrate is Si and an SO_2 film is etched thereon. Further, since a resist is also etched by F, selectivity to the resist cannot be obtained as well. Accordingly, an F-enriched plasma is not suitable to the etching of the insulating film. In a case where the plasma excitation frequency is as high as 2.45 GHz, gas dissociation proceeds to form an F-enriched plasma. In this case, although the etching rate is high, the selectivity is lowered.

On the other hand, CF_2 does not react without ion irradiation and etching proceeds only by ion irradiation at a high energy.

Further, when fine holes of an insulating film are etched by a plasma comprising F, CF, CF_2 and CF_3, CF_x as an etchant has to reach as far as the bottom of the fine holes. However, since the adsorption probability of respective radicals are different, their ratio should be selected properly. For this purpose, it is necessary to actually optimize species, and flow rate of the gas to be added, pressure and plasma generating conditions. This requires setting of conditions that satisfy individual demands. However, such etching conditions cannot be determined easily even when the mechanisms described above were known.

The Examiner comments that "selection and specification for the kind of the gas species is an industrially customary procedure. This statement is accurate on its face. However, it is uncertain what gas should be used for etching a certain material (thin film), which can not be determined merely based on the common knowledge.

Referring to the gas species, the material to be etched in the cited reference Satou is a metal wiring material such as aluminum, and that of Nishino is polysilicon. The present invention, on the other hand, is

directed to insulating films such as made of SiO_2, which is different in the etching mechanism from materials of the cited references. Accordingly, it is respectfully submitted that the Examiner is in error in stating that "gas species suitable to etching can be estimated easily also in the case of the present invention in view of Nishino or Satou".

Moreover, it is respectfully submitted that the Examiner is in error in asserting that Satou et al provides specific motivation for the selection of alternative etching gases to influence "wafer yield stability and reliability." The referenced Col. 5, lines 10 - 29 do not say this at all. Rather, the referenced passage implies that the etching gas is selected as being compatible with the material.

The use of a gas containing F and C for the etching of the insulating film is known. Further, the Examiner is correct in stating that "It is well known that when the frequency of a plasma source is changed, the plasma excitation frequency changes correspondingly".

However, it is not known what range of frequency should be chosen for etching a certain kind of insulating film. Although varying on the gas species, the degree of dissociation greatly depends on the frequency and, accordingly, the frequency has to be selected so as to be suitable on every insulating film, and the radical density

distribution for F, CF, CF_2 and CF_3 have to be determined to an appropriate ratio.

As described above, the optimal frequency range as the feature of our invention is not obvious in view of Nishino, Satou and Kuhn and is not a mere matter of discovering optimum or workable ranges by routine experimentation.

Finally, for the setting of the wall surface temperature, in Satou, the temperature in the etching chamber in which the plasmas are formed (space as described above the wafer) is set to 100°C or higher, so that reaction products $AlCl_3$ are not deposited on the wall surface. In the processing chamber itself, Satou et al clearly teaches away from cooling the side walls of the reaction chamber and instead teaches that these wall should be kept at an elevated temperature to avoid the deposition of reaction products thereon. On the other hand, the temperature on the wall surface at the downstream to the wafer is made lower so as to deposit the reaction products. The wall surface temperature is defined so that deposition films on the wall surface are prevented from falling as obstacles on the wafer.

In the oxide film etching apparatus prior to the present invention, the temperature of the wall surface is usually maintained high so as not to form deposition films in the etching chamber. For example, in the example

described, for example, by S. C. McNevin, et al., in Journal of Vacuum Science and Technology, B15(2), 1997, pp. 214 0 220: "Chemical Challenge of Submicron Oxide Etching", the temperature on the wall surface is set to 220°C. The F content is inevitably increased in high density plasmas. Accordingly, the method of this reference involves relatively increasing CF_2 by detaching CF_2 from the deposition film on the wall surface. To accomplish this, the temperature on the wall surface is made high.

The wall surface temperature and release of CF or the like are described, for example, by H. Sugai, et al., in Journal of Vacuum Science and Technology, A13(3), 1995, p. 887: Diagnostic and Control of Radicals in an Inductively Coupled Etching Reactor.

The present invention, on the other hand, relates to the following features in combination: "(a) the plasma frequency is defined as from 300 MHz to 1 GHz to control dissociation of F and C and (b) side wall is maintained at a low temperature (10 to 120°C)", thereby capable of suppressing the generation of obstructing material and enabling etching at high selectivity with no requirement for the supply of CF_2 or the like from the wall surface. As discussed above, this combination is neither described nor suggested by Satou or Nishino. Accordingly, Claims 1, 2, 4, 5, 6, 7, 9 and 10 would not have been obvious over Satou et al (U.S. Patent No. 5,961,850) in view of H.

Conclusion

In view of the foregoing amendments and remarks, it is respectfully submitted that Claims 1, 2, 4, 5, 6, 7, 9 and 10 are in condition for allowance. Favorable reconsideration is respectfully requested.

To the extent necessary, Applicants petition for an extension of time under 37 CFR § 1.136. Please charge any shortage in fees due in connection with the filing of this paper, including extension of time fees, to the Deposit Account No. 01-2135 (Case No. 520.37698X00) and please credit any excess fees to such Deposit Account.

Respectfully submitted,

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RTW/RTW

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1. (four times amended) In a plasma processing apparatus for etching an electrically insulating film, the plasma processing apparatus having a vacuum processing chamber, a sample table for mounting a sample which is processed in said vacuum processing chamber, and a plasma generation means, wherein a plasma processing is carried out by generating a plasma in response to introduction of a gas which contains at least carbon and fluorine, and a gas species is generated which contains carbon and fluorine according to a plasma dissociation, the plasma processing apparatus comprising:

plasma generation means comprising an electron cyclotron resonance system in which a microwave is provided having a frequency of from 300 MHz to 1 GHz and which generates a plasma in which the degree of plasma dissociation is an intermediate degree and said gas species containing carbon and fluorine is generated fully in the plasma, and a temperature of a region which forms a side wall of said vacuum processing chamber is controlled to have a range of 10 °C to 120 °C and wherein the sample for etching by the plasma is an insulating film.

6. (four times amended) In a plasma processing method using a vacuum processing chamber, a sample table for

mounting a sample which is processed in said vacuum processing chamber wherein the sample is an electrically insulating film, and a plasma generation means, wherein a plasma processing is carried out by generating a plasma in response to introduction of a gas which contains at least carbon and fluorine, and a gas species is generated which contains a carbon and fluorine according to a plasma dissociation, the plasma processing method comprising the steps of:

generating a plasma, wherein said plasma generation is effected using an electron cyclotron resonance system in which a microwave having a frequency of from 300 MHz to 1 GHz is employed and wherein a degree of plasma dissociation is an intermediate degree and said gas species containing carbon and fluorine is generated fully in the plasma, and controlling a temperature of a region which forms a side wall of said vacuum processing chamber to have a range of 10 °C to 120 °C.